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THE NETHERLANDS

7419294001

4. Title of the invention

RADIO COMMUNICATION SYSTEM

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent, (including the postcode)

Kevin James SCOTT  
Philips Corporate Intellectual Property  
Cross Oak Lane  
Redhill  
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Country	Priority Application number (if you know it)	Date of filing (day/month/year)
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Date 23<sup>rd</sup> September 1999

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01293 815281

(Kevin J. Scott)

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## DESCRIPTION

**RADIO COMMUNICATION SYSTEM**

5       The present invention relates to a radio communication system and further relates to primary and secondary stations for use in such a system and to a method of operating such a system. While the present specification describes a system with particular reference to the emerging Universal Mobile Telecommunication System (UMTS), it is to be understood that such  
10 techniques are equally applicable to use in other mobile radio systems.

      There are two basic types of communication required between a Base Station (BS) and a Mobile Station (MS) in a radio communication system. The first is user traffic, for example speech or packet data. The second is control  
15 information, required to set and monitor various parameters of the transmission channel to enable the BS and MS to exchange the required user traffic.

      In many communication systems one of the functions of the control information is to enable power control. Power control of signals transmitted to  
20 the BS from a MS is required so that the BS receives signals from different MS at approximately the same power level, while minimising the transmission power required by each MS. Power control of signals transmitted by the BS to a MS is required so that the MS receives signals from the BS with a low error rate while minimising transmission power, to reduce interference with other  
25 cells and radio systems. In a two-way radio communication system power control is normally operated in a closed loop manner, whereby the MS determines the required changes in the power of transmissions from the BS and signals these changes to the BS, and vice versa.

      An example of a combined time and frequency division multiple access  
30 system employing power control is the Global System for Mobile communication (GSM), where the transmission power of both BS and MS transmitters is controlled in steps of 2dB. Similarly, implementation of power

control in a system employing spread spectrum Code Division Multiple Access (CDMA) techniques is disclosed in US-A-5 056 109.

5 A problem with these known techniques is that at the start of a transmission, or after the transmission is interrupted or the target power is abruptly changed, the power control loops may take some time to converge satisfactorily, since the initial power levels are derived from open loop measurements which may not be sufficiently accurate as the channels on which they were made are likely to have different characteristics from the newly initiated channels.

10

An object of the present invention is to alleviate the above problem.

According to a first aspect of the present invention there is provided a radio communication system comprising a primary station and a plurality of secondary stations, the system having a communication channel between the  
15 primary station and a secondary station, the channel comprising an uplink and a downlink control channel for transmission of control information, and a data channel for the transmission of data packets, characterised in that the primary and secondary stations have means for delaying the initial transmission of the data channel until after initial transmission of the control channels.

20 According to a second aspect of the present invention there is provided a radio communication system comprising a primary station and a plurality of secondary stations, the system having a communication channel between the primary station and a secondary station, the channel comprising an uplink and a downlink control channel for transmission of control information, and a data  
25 channel for the transmission of data packets, and the primary and secondary stations having power control means for adjusting the power of the control and data channels in a series of steps of variable size, characterised in that the size of the power control steps is initially large and reduces as the power approaches its target value.

30 According to a third aspect of the present invention there is provided a radio communication system comprising a primary station and a plurality of secondary stations, the system having a communication channel between the

primary station and a secondary station, the channel comprising an uplink and a downlink control channel for transmission of control information, and a data channel for the transmission of user data, and the primary and secondary stations having power control means for adjusting the power of the control and data channels, characterised in that the secondary station has means for determining a weighted average of its transmission power over a predetermined period and means for setting the initial transmission power after a pause in transmission depending on a weighted average power determined before the pause.

According to a fourth aspect of the present invention there is provided a primary station for use in a radio communication system made in accordance with the present invention.

According to a fifth aspect of the present invention there is provided a secondary station for use in a radio communication system made in accordance with the present invention.

According to a sixth aspect of the present invention there is provided a method of operating a radio communication system made in accordance with the present invention, characterised by delaying the initial transmission of the data channel until after the initial transmission of the control channels.

According to a seventh aspect of the present invention there is provided a method of operating a radio communication system made in accordance with the present invention, characterised by reducing the size of the power control steps as the power approaches its target value.

According to an eighth aspect of the present invention there is provided a method of operating a radio communication system made in accordance with the present invention, characterised by the secondary station determining a weighted average of its transmission power over a predetermined period and setting the initial transmission power after a pause in transmission depending on a weighted average power determined before the pause.

The use of more than one power control step size is known, for example from JP-A-10224294. However its use in this citation is limited to situations where power control is already established but propagation conditions are

fluctuating rapidly. This citation does not address the problem of obtaining rapid convergence of power control at the start of, or after an interruption in, a transmission.

5        Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a block schematic diagram of a radio communication system;

10        Figure 2 illustrates a conventional scheme for establishing a communication link;

Figure 3 illustrates a scheme in accordance with the present invention for establishing a communication link, having a delayed start to data transmission;

15        Figure 4 is a flow chart illustrating a method in accordance with the present invention for performing power control operations having a variable step size;

20        Figure 5 is a graph of received signal power (P) in dB against time (T) in ms for different power control algorithms, the solid line indicating results with no power control, the chain dashed line indicating results with power control having a single step size, and the dashed line indicating results with power control having two step sizes; and

25        Figure 6 is a graph of received signal power (P) in dB against time (T) in ms for different power control algorithms, the solid line indicating results with no power control, the chain dashed line indicating results with power control having a single step size, and the dashed line indicating results with power control having three step sizes.

In the drawings the same reference numerals have been used to indicate corresponding features.

30        Referring to Figure 1, a radio communication system which can operate in a frequency division duplex mode comprises a primary station (BS) 100 and a plurality of secondary stations (MS) 110. The BS 100 comprises a



microcontroller ( $\mu$ C) 102, transceiver means (Tx/Rx) 104 connected to radio transmission means 106, power control means (PC) 107 for altering the transmitted power level, and connection means 108 for connection to the PSTN or other suitable network. Each MS 110 comprises a microcontroller ( $\mu$ C) 112, transceiver means (Tx/Rx) 114 connected to radio transmission means 116, and power control means (PC) 118 for altering the transmitted power level. Communication from BS 100 to MS 110 takes place on a downlink frequency channel 122, while communication from MS 110 to BS 100 takes place on an uplink frequency channel 124.

One UMTS embodiment uses the scheme of Figure 2 for establishing a communication link between MS 110 and BS 100. The link is initiated by the MS 110 transmitting a request 202 (REQ) for resources on the uplink channel 124. If it receives the request and has available resources, the BS 100 transmits an acknowledgement 204 (ACK) on the downlink channel 122 providing the necessary information for communication to be established. After the acknowledgement 204 has been sent, two control channels (CON) are established, an uplink control channel 206 and a downlink control channel 208, and an uplink data channel 210 is established for transmission of data from the MS 110 to the BS 100.

In this scheme separate power control loops operate in both uplink 124 and downlink 122 channels, each comprising an inner and an outer loop. The inner loop adjusts the received power to match a target power, while the outer loop adjusts the target power to the minimum level that will maintain the required quality of service (i.e. bit error rate). However, this scheme has the problem that when transmissions start on the control channels 206, 208 and data channel 210 the initial power levels and quality target are derived from open loop measurements, which may not be sufficiently accurate as the channels on which the measurements were made are likely to have different characteristics from the newly initiated channels. The result of this is that data transmissions at the start of the data channel 210 are likely to be received in a corrupted state if they are transmitted at too low a power level, or to generate extra interference if they are transmitted at too high a power level.

One known partial solution to this problem is for the BS 100 to measure the received power level of the request 202 and to instruct the MS 110, within the acknowledgement 204, an appropriate power level for the uplink data transmission 210. This improves matters, but there may still be errors introduced by the temporal separation between the request 202 and the start of the uplink data transmission 210.

Figure 3 illustrates a solution to the problem in accordance with the present invention, in which the start of the uplink data transmission 210 is delayed by a time 302 sufficient for the power control to have converged sufficiently to enable satisfactory reception of data transmissions by the BS 100. A delay of one or two frames (10 or 20ms) is likely to be sufficient, although longer delays 302 may be permitted if necessary. The additional overhead in the transmission of extra control information on the control channels 206, 208 is balanced by a reduced  $E_b/N_0$  (energy per bit / noise density) for the user data received by the BS 100 over the data channel 210. The delay 302 could be predetermined or it could be determined dynamically, either by the MS 110 (which could detect convergence by monitoring downlink power control information) or the BS 100.

Figure 4 is a flow chart showing another solution to the problem in accordance with the present invention, in which the power control step size is variable. Since the power control error is likely to be greatest at the start of a transmission or after an idle period, the optimum power control step size will be larger than that used for normal operation

The method starts 402 with the beginning of the transmissions of the control channels 206, 208 and the data channel 210 (or the beginning of their retransmission after an interruption). The difference between the received power and target power is then determined at 404. Next the power control step size is tested at 406 to determine whether it is greater than the minimum. If it is the power control step size is adjusted at 408 before adjustment of the power at 410. The change in step size could be deterministic, or based on previous power control adjustments or on some quality measurement. The power control loop then repeats, starting at 404.

In one embodiment of the present invention, it is preferred to set the power control step size initially to a large value, then reduce it progressively until it reaches the value set for normal operation (which may be cell or application specific). Preferably the ratio between successive step sizes is no more than two, to allow for the possibility of correcting errors in transmission or due to other factors. The power control step size could be changed in both uplink 124 and downlink 122 channels.

As an example, consider an initial sequence of power control step sizes (in dB) of: 3.0, 2.0, 1.5, 1.0, 0.75, 0.75, 0.5, 0.5, 0.25, where 0.25dB is the minimum step size. Using this sequence with power control signals every 1ms, an initial error of up to 10dB could be corrected within half a frame (5ms), compared with 2.5 frames using the minimum power control step size of 0.25dB that is normally used. Although as described here the step sizes are symmetric (i.e. the same step sizes are applicable to increases or decreases in power), it is known (for example from US-A-5 056 109) that this is not always appropriate. In a similar example, which would be simpler to implement, the initial step size (e.g. 2dB) is used for a predetermined number of power control commands, after which the step size is reduced (e.g. to 1dB).

The selection of initial step size and the rate of change could be predetermined, or determined dynamically. For example, if the power level adjustment signalled in the acknowledgement 204 is large then the initial step size could be increased. As another example, if the MS 110 is able to determine by other means that it has a moderately high speed relative to the BS 100 a larger step size may be appropriate.

A fixed power control adjustment could be applied at the start of the transmission. This could be done even before receipt of any valid power control command, but the size and direction might be predetermined or determined dynamically, for example, using information such as the rate of change of the channel attenuation derived from receiver measurements. Under some channel conditions this gives an improvement in performance. Increasing the power in this way is particularly suited to the case of re-starting

a transmission after an interruption, where the state of the power control loop (e.g. current power level) may be retained from before the interruption.

In rapidly changing fading channels the channel attenuation following a gap in transmission is likely to be uncorrelated with that immediately before the gap. In such a case it may be argued that the optimum value of the initial transmission power after the gap will be equal to its average value (ignoring other slow fading effects like shadowing). This will then minimise the difference between the initial value and the optimum instantaneous value due to channel fluctuations. In practice, the transmission power at the end of the gap could be determined from a weighted average of the power over some extended period before the gap. A suitable averaging period would depend on particular conditions but could be of the order of 20 slots (i.e. 20 power control cycles). An additional offset or fixed power adjustment could be applied to this initial power level. Optimum values of such offsets for particular circumstances could be determined empirically.

In practice it may be simpler to determine the initial power from a weighted sum of power control commands, rather than measure the transmitted power. In this case the change in power (in dB) which would need to be applied after a transmission gap could be computed recursively in the following way:

$$\Delta P(t) = P_{off} + K_1 \times (\Delta P(t-1) - P_{off}) - K_2 \times PC(t) \times PS(t)$$

where:

$\Delta P(t)$  is the change in power which would be applied after a gap, computed at time  $t$ ;

$\Delta P(0)$  could be initialised to zero;

$P_{off}$  is an additional power offset;

$K_1$  and  $K_2$  are empirically determined constants, which could be equal, such that  $0 \leq K \leq 1$ . The values of these constants can be chosen to reflect the effective averaging period used in calculating the power change;

$PC(t)$  is power control command applied at time  $t$ ; and

$PS(t)$  is the power control step size used at time  $t$ .

Before it is used the value of  $\Delta P(t)$  would need to be quantised to an available power control step size.

One example of an embodiment in which the selection of step size is determined dynamically uses the sign of the received power control bits to determine the step size. When the MS 110 starts to receive power control commands it uses the largest available step size, and continues to use this step size until a power control command of opposite sign is received when the step size is reduced. This next step size is used until the sign of the power control commands is reversed, when the step size is again reduced. This process continues until the minimum step size is reached.

Figure 5 is a graph showing the effect of this method in a system having two step sizes available. The graph shows how the received signal power (P) in dB, relative to a target power of 0dB, varies with time (T). The solid line shows the received signal power without use of power control. The variation in received power could for example be due to the motion of the MS 110. The chain-dashed line shows the received power with use of power control having a single step size of 1dB. The dashed line shows the received power with the use of power control in accordance with the present invention.

In this method, when use of power control begins, at 2ms, a larger step size of 2dB is used. Initially the received power is less than the target power, so all the power control commands request an increase in power and the 2dB step size continues to be used. Eventually, at about 6ms, the received power exceeds the target power. Once this happens the sign of the power control command reverses, to request a decrease in power, which also has the effect of reducing the step size to the standard step size of 1dB. This step size then continues to be used in response to subsequent power control commands. It is apparent from Figure 5 that use of the method in accordance with the present invention enables the received power to reach its target more rapidly than is possible with a single step size. Once the target has been reached, the reduction in step size to the standard step size enables accurate power control to be maintained. Such a method enables cases where the initial error is large

or the channel is rapidly changing to be handled effectively, as well as cases where convergence is achieved quickly.

The method can also be used with a greater number of available step sizes. Figure 6 shows the same example as Figure 5 with the exception that the dashed line shows the received power with the use of power control having three step sizes, 4dB, 2dB and 1dB, available. Initially a 4dB step size is used, with the result that the power reaches the target much more rapidly than in the previous example. When the sign of the power control command reverses, to request a reduction in power, the step size is reduced to 2dB. When the power control command reverses again, to request an increase in power, the step size reduces to the standard step size of 1dB, where it remains.

A variation of the above method is to continue using the larger step size for one slot after the change in sign of the power control command, which could help to correct any overshoot. However, this is unlikely to have a major impact on the average performance of the method.

Combinations of the techniques described above can readily be used to provide improved results.

Although the description above has examined data transmission on the uplink channel 124, the techniques are equally applicable to data transmission on the downlink channel 122 or to bidirectional transmissions.

Embodiments of the present invention have been described using spread spectrum Code Division Multiple Access (CDMA) techniques, as used for example in UMTS embodiments. However, it should be understood that the invention is not limited to use in CDMA systems. Similarly, although embodiments of the present invention have been described assuming frequency division duplex, the invention is not limited to use in such systems. It may also be applied to other duplex methods, for example time division duplex (although the power control rate in such a system would normally be limited to once per transmission burst).

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in radio communication systems and

component parts thereof, and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any  
5 novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be  
10 formulated to such features and/or combinations of features during the prosecution of the present application or of any further application derived therefrom.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.  
15 Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

## CLAIMS

1. A radio communication system comprising a primary station and  
5 a plurality of secondary stations, the system having a communication channel  
between the primary station and a secondary station, the channel comprising  
an uplink and a downlink control channel for transmission of control  
information, and a data channel for the transmission of data packets,  
characterised in that the primary and secondary stations have means for  
10 delaying the initial transmission of the data channel until after initial  
transmission of the control channels.

2. A system as claimed in claim 1, characterised in that the delay in  
transmission of the data channels is sufficient to enable the power control  
15 means to have substantially corrected the difference between initial and target  
power levels in the control channels.

3. A system as claimed in claim 1 or 2, characterised in that the  
delay in transmission of the data channels is predetermined.  
20

4. A system as claimed in claim 1 or 2, characterised in that the  
delay in transmission of the data channels is determined dynamically.

5. A system as claimed in any one of claims 1 to 4, characterised in  
25 that the primary and secondary stations comprise power control means for  
adjusting the power of the control and data channels in a series of steps  
towards a target power.

6. A radio communication system comprising a primary station and  
30 a plurality of secondary stations, the system having a communication channel  
between the primary station and a secondary station, the channel comprising  
an uplink and a downlink control channel for transmission of control



information, and a data channel for the transmission of data packets, and the primary and secondary stations having power control means for adjusting the power of the control and data channels in a series of steps of variable size, characterised in that the size of the power control steps is initially large and  
5 reduces as the power approaches its target value.

7. A system as claimed in claim 6, characterised in that the primary and secondary stations comprise signal power measuring means and in that the power control means adjusts the size of the power control steps in  
10 response to the measured signal power.

8. A system as claimed in claim 6 or 7, characterised in that the primary and secondary stations comprise means for storing predetermined sequences of power control step sizes and in that means are provided for  
15 selecting one of said predetermined sequences.

9. A system as claimed in any one of claims 6 to 8, characterised in that the power control step size is reduced when the sign of a power control command reverses.  
20

10. A radio communication system comprising a primary station and a plurality of secondary stations, the system having a communication channel between the primary station and a secondary station, the channel comprising an uplink and a downlink control channel for transmission of control  
25 information, and a data channel for the transmission of user data, and the primary and secondary stations having power control means for adjusting the power of the control and data channels, characterised in that the secondary station has means for determining a weighted average of its transmission power over a predetermined period and means for setting the initial  
30 transmission power after a pause in transmission depending on a weighted average power determined before the pause.

11. A system as claimed in claim 10, characterised in that the initial transmission power is set to the last weighted average power determined before the pause.

5 12. A system as claimed in claim 10, characterised in that the initial transmission power differs from the previously determined weighted average power by an offset.

10 13. A system as claimed in claim 12, characterised in that the offset is predetermined.

14. A primary station for use in a radio communication system as claimed in any one of claims 1 to 13.

15 15. A secondary station for use in a radio communication system as claimed in any one of claims 1 to 13.

20 16. A method of operating a radio communication system as claimed in any one of claims 1 to 5, characterised by delaying the initial transmission of the data channel until after the initial transmission of the control channels.

25 17. A method of operating a radio communication system as claimed in any one of claims 6 to 9, characterised by reducing the size of the power control steps as the power approaches its target value.

30 18. A method of operating a radio communication system as claimed in any one of claims 10 to 13, characterised by the secondary station determining a weighted average of its transmission power over a predetermined period and setting the initial transmission power after a pause in transmission depending on a weighted average power determined before the pause.

19. A radio communication system substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

20. A primary station for use in a radio communication system  
5 substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

21. A secondary station for use in a radio communication system  
10 substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

22. A method of operating a radio communication system  
substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

## ABSTRACT

## RADIO COMMUNICATION SYSTEM

5

A radio communication system has means for ensuring that power control of a channel has been established for the transmission of data. In one embodiment the transmission of a data channel can be delayed until adequate power control has been established. In another embodiment power control can be applied in steps of varying size. In a further embodiment the transmission of a data channel can be delayed until adequate power control has been established by changing power in a sequence of steps of varying size. These techniques overcome the problem that data transmissions at the start of a data channel are likely to be corrupted if the power level is too low, or to generate extra interference if the power level is too high.

15

(Figure 4)

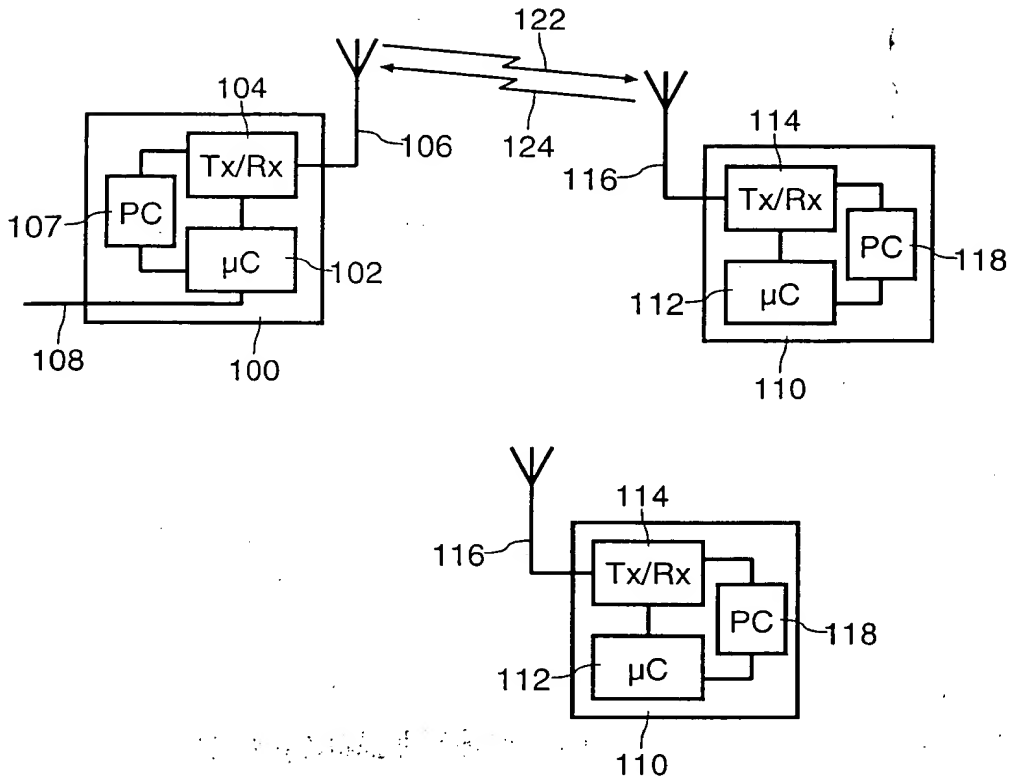


FIG. 1

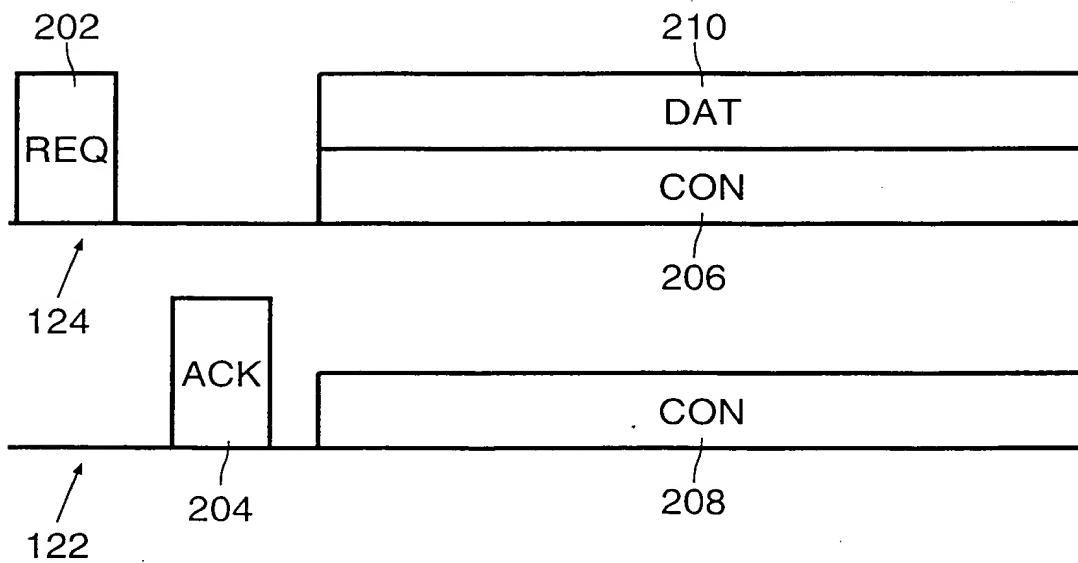


FIG. 2

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2/3

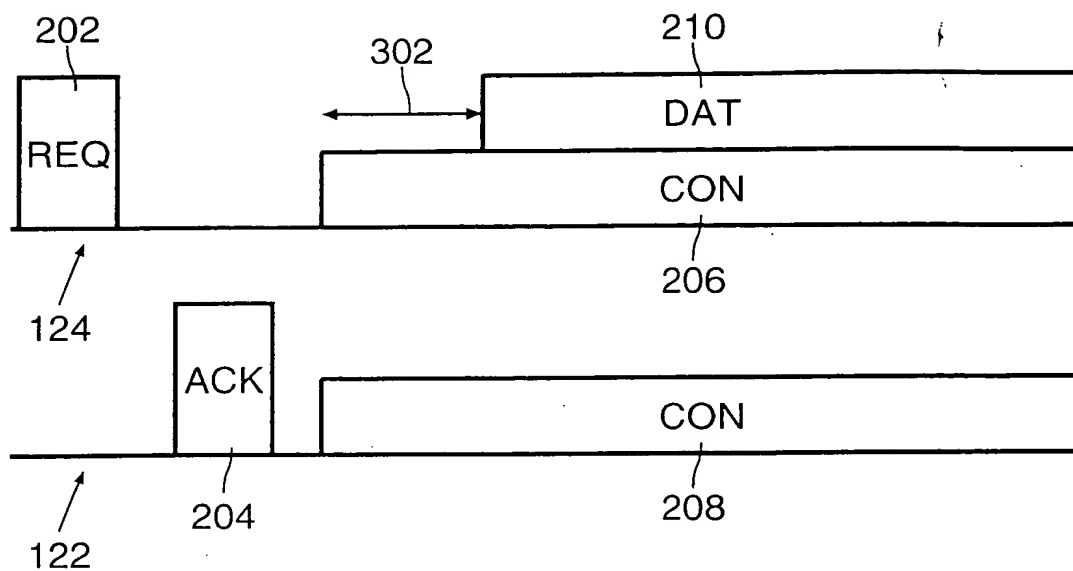


FIG. 3

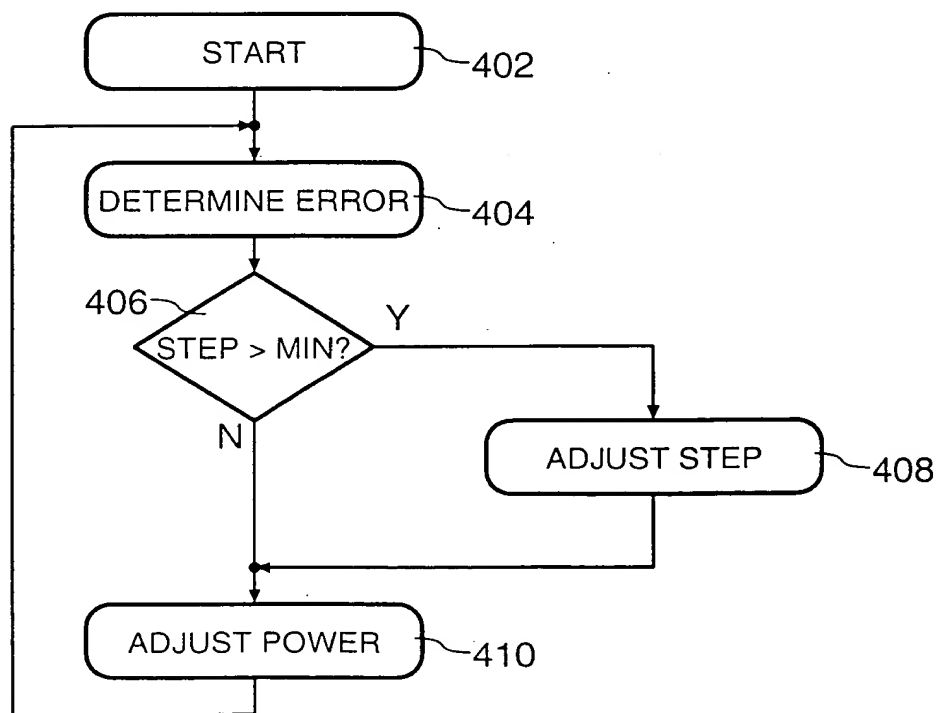


FIG. 4

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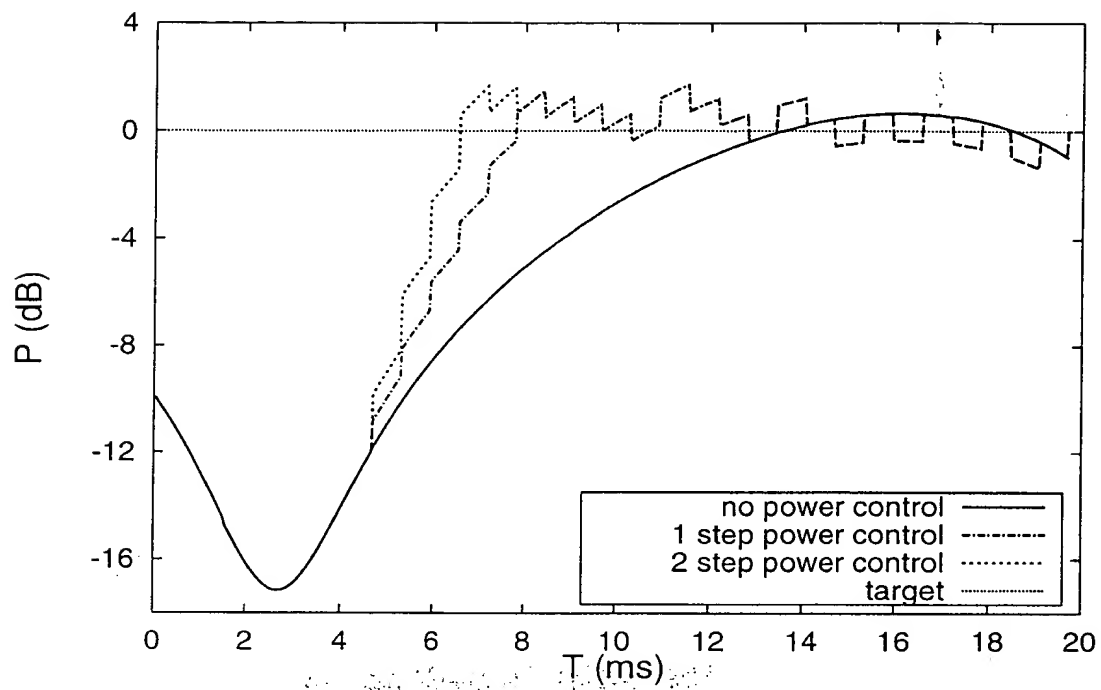


FIG. 5

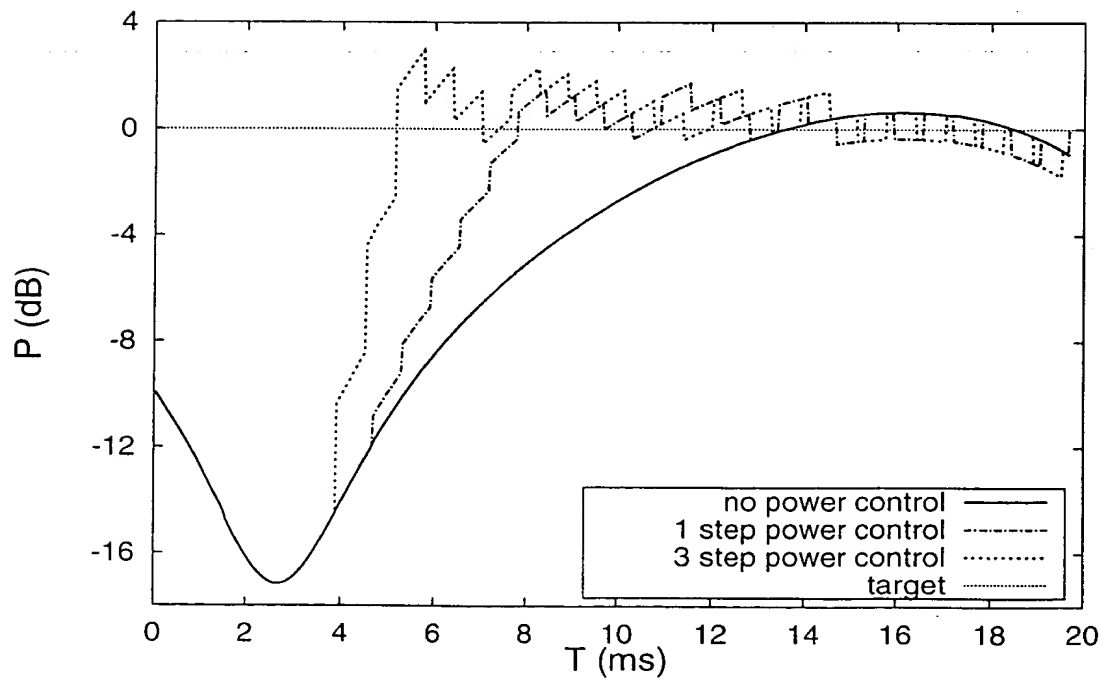


FIG. 6

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